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Teams with moral hazard and non-verifiable quality assessment☆

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HIGHLIGHTS

- We study a static moral hazard setting with non-contractible quality.
- The buyer privately observes quality before trade.
- Sellers have private information about the cost and choice of effort.
- The buyer prefers to contract with a team rather than with each seller individually.

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ABSTRACT

This paper shows that buying from a team of sellers can be optimal for the buyer in a static model where the buyer has private information about quality, sellers have private information about the cost and choice of effort, and quality is not contractible.

1. Introduction

This paper studies when contracting with a team of agents rather than with each agent individually to trade a good is beneficial to the principal in an environment with moral hazard and non-contractible quality. We consider a static model where a buyer (principal) has private information about product quality, sellers (agents) have private information about the cost and choice of effort and are protected by limited liability, and a feasible contract can only have payments that are contingent on the volume of trade. For example, these modeling assumptions may describe contracting in an agricultural market with collective selling by smallholder farmers in a developing country (e.g. Holloway et al., 2000). In this setting moral hazard arises even if the buyer can perfectly infer the seller's efforts. Suppose that the buyer contracts with a seller individually in the sense that the buyer decides whether to buy the product from that seller independently of her other purchasing decisions. The seller will then be tempted to reduce the buyer's gain from trade until the buyer is just indifferent between buying and rejecting the product. If the seller has perfect information about the buyer's willingness to pay, the buyer's rent will be completely dissipated. In this case, formation of a small team of sellers mitigates their temptation to shirk on quality in spite of the free-riding problem. This happens because joint selling introduces endogenous uncertainty about the quality of the team's output that makes low-cost sellers more willing to exert greater efforts in order to increase the probability of sale. [1]

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[1] Section 4 demonstrates that formation of teams can also be optimal when signals are noisy.

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The idea that an endogenous and strategic introduction of type uncertainty can improve reputation building in small teams (partnerships) is explored in Bar-Isaac (2007).[2] Here we show that the buyer can also benefit from team production. Our paper is related to the literature on the endogenous team size and moral hazard in the presence of subjective evaluations. Auriol et al. (2002) and Rauh (2015) consider complementary efforts that capture production activities performed within firms. In our case, efforts are substitutable and the principal observes performance before trade occurs. In Liang et al. (2008), efforts are substitutable but the firm employs at most one team of workers, while our buyer can hire multiple one-seller teams.

Rejection of the agent's product represents a short-term punishment that corresponds to contract termination in a principal–agent model with relational contracting and subjective monitoring of the agent's performance (e.g. Levin, 2003). This paper demonstrates that, unlike in the dynamic models of moral hazard with repeated interaction, in the presence of purely short-term incentives the principal may prefer to inject additional noise into the agent's assessment of her benefit from the relationship.

2. Model

We consider a static model with a profit-maximizing principal (buyer) and two identical agents (sellers), A and B. All players are risk-neutral and the outside options of all players are normalized to zero. Each seller i produces at most one unit at no cost and privately chooses the level of effort $e_i \geq 0$ at cost $C(e_i\theta_i)$, where C is a strictly increasing, convex, and twice differentiable function with $C(0) = 0$, $C'(0) \geq 1$, and inverse C^{-1}. Seller i's "type" $\theta_i \in [0, 1]$ is independently drawn from a continuous differentiable distribution F with a strictly positive density f on $[0, 1]$. Each seller is privately informed about her own type, but it is not observed by the other seller and the buyer. From each unit the buyer obtains utility $q_i = e_i$ if unit i is purchased, and zero utility if the unit is not purchased. The buyer can buy from each seller i individually, $b_i \in \{0, 1\}$, or jointly from a team of two sellers, $b \in \{0, 2\}$. In the latter case, the buyer is constrained to buy either both units or none.[3] If the sellers sell individually, the buyer observes q_i before making a purchasing decision. If the sellers sell jointly as a team, the buyer only observes the average quality, $y = \frac{1}{2}(q_1 + q_2)$.[4] Under both individual and joint selling, the signals of quality are not verifiable.

Under individual selling, the buyer offers a contract (w_0, w_1) to each seller i with transfers that depend on the acceptance or rejection of the seller's product, $b_i \in \{0, 1\}$. Under joint selling, the buyer offers a contract (w_0, w_2) to each seller with transfers that depend on the acceptance or rejection of the team's output, $b \in \{0, 2\}$.[5] We assume that the sellers are subject to limited liability and cannot be forced to make positive transfers to the buyer, $w_0, w_1, w_2 \geq 0$. Under individual selling the buyer's per seller average profit is $\frac{1}{2}\sum_{i\in\{A,B\}} b_i q_i - w_{b_i}$, and the payoff of seller i is $w_{b_i} - C(e_i\theta_i)$. Under joint selling, the buyer's per seller profit is $\frac{1}{2}by - w_b$, and the payoff of seller i is $w_b - C(e_i\theta_i)$.

The game proceeds as follows.

1. The buyer publicly chooses whether she will trade with each seller individually or as a team.
2. The buyer offers a contract (w_0, w_1) under individual selling or (w_0, w_2) under joint selling to each seller.
3. Each seller privately observes his cost θ_i and chooses the level of effort, e_i.
4. The buyer privately observes the individual quality, q_i, or the average quality, y.
5. The buyer decides whether to buy or reject individual products, b_i, or the team's output, b.
6. The payoffs are realized.

3. Equilibrium

We solve for a subgame perfect equilibrium. The first-best level of effort that maximizes surplus from trade, $W(e, \theta) = e - C(\theta e)$, is given by $e^{FB}(\theta) = C'^{-1}(1/\theta)/\theta$ for $\theta \leq \theta^{FB}$ and $e^{FB}(\theta) = 0$ for $\theta > \theta^{FB}$, where $\theta^{FB} \in (0, 1)$ solves $W(e^{FB}(\theta^{FB}), \theta^{FB}) = C'^{-1}(1/\theta^{FB})/\theta^{FB} - C(C'^{-1}(1/\theta^{FB})) = 0$, so that only trade with low-cost sellers, $\theta_i \leq \theta^{FB}$, is efficient.

3.1. Individual selling

Under individual selling the buyer cannot earn a positive profit when sellers have perfect information about the buyer's valuation for the good. To see why, note that the buyer purchases a seller's product if

$$e_i - w_1 \geq -w_0. \tag{1}$$

Therefore, a seller leaves the buyer indifferent between buying and not buying, $e_i = w_1 - w_0$, if $w_1 - w_0 - C(\theta_i[w_1 - w_0]) \geq 0$, or exerts zero (the lowest possible) effort, $e_i = 0$, if $w_1 - w_0 - C(\theta_i[w_1 - w_0]) < 0$. Summarizing, the unique equilibrium effort strategy is given by

$$e_1^*(\theta_i) = \begin{cases} w_1 - w_0, & \text{if } \theta_i \leq C^{-1}(w_1 - w_0)/(w_1 - w_0) \\ 0, & \text{if } \theta_i > C^{-1}(w_1 - w_0)/(w_1 - w_0) \end{cases}, \tag{2}$$

where subscript "1" denotes the "individual selling" regime. Since $e_1^*(\theta_i) - w_1 \leq 0$ for any $w_0, w_1 \geq 0, \theta_i \in [0, 1]$, the buyer can achieve at most zero profit.

Proposition 1. *In equilibrium the buyer earns zero profit under individual selling.*

3.2. Joint selling

Under joint selling the buyer accepts the team's output if

$$y - w_2 \geq -w_0, \tag{3}$$

and the expected profit of seller i is given by

$$\Pr\{y \geq w_2 - w_0\}(w_2 - w_0) + w_0 - C(\theta_i e_i). \tag{4}$$

Conditional on contract (w_0, w_2) having being signed by both sellers, a pure strategy Nash equilibrium at the effort choice stage is a function $e_2^* : [0, 1] \to \Re_+$ such that

$$e_2^*(\theta) \in \arg\max_{e\geq 0} \Pr\left\{\frac{1}{2}[e + e_2^*(\theta_i)] \geq w_2 - w_0\right\}(w_2 - w_0) + w_0 - C(\theta e) \quad \text{for each } \theta \in [0, 1]. \tag{5}$$

Here subscript "2" denotes the "joint selling" regime.

First, note that an outcome where each seller exerts the same minimum effort that leaves the buyer indifferent, $e_i = w_2 - w_0$ for all $\theta_i \in [0, 1]$, is not an equilibrium, because $w_2 - C(\theta_i(w_2 - w_0)) < w_0$ for all θ_i close to 1 for any $w_2 - w_0 > 0$. Therefore, in any equilibrium with trade it must be that e_2^* is a non-increasing function of seller's type with $e_2^*(0) > e_2^*(1)$. This means that there

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[2] Peer 0monitoring can also mitigate free-riding in teams concerned with reputation building (Saak, 2012).

[3] We could easily allow the buyer to buy a fraction of output. A risk-neutral buyer will prefer to buy all or none of the team's output if the purchased fraction of output is chosen at random.

[4] One example is dairy farmers pooling their milk before the buyer assesses milk quality.

[5] These individual contracts are equivalent to a group contract.

exists a threshold type $\hat{\theta} \in (0, 1)$ such that $e_2^*(\theta) > w_2 - w_0$ for $\theta \leq \hat{\theta}$ and $e_2^*(\theta) \leq w_2 - w_0$ for $\theta > \hat{\theta}$, because otherwise it must be that either $e_2^*(\theta) \leq w_2 - w_0$ or $e_2^*(\theta) \geq w_2 - w_0$ for all θ, which cannot be the best response for all types. Second, note that the sellers will sign a contract with $(w_0, w_2) = (0, w)$ for any $w > 0$ as it guarantees them a non-negative payoff.

Therefore, in any equilibrium the buyer can earn a strictly positive expected (per seller) profit:

$$\frac{1}{2}E\left[\max\left[\sum_{i\in\{A,B\}} e_2^*(\theta_i) - 2w, 0\right]\right] \geq F^2(\hat{\theta})[e_2^*(\hat{\theta}) - w] > 0. \quad (6)$$

The first inequality follows because, under a contract $(w_0, w_2) = (0, w)$, the buyer can always earn a zero payoff ex post (after the team's output is offered for sale) by rejecting the team's output, and $e_2^*(\theta) \geq e_2^*(\hat{\theta}) > w$ for all $\theta \leq \hat{\theta}$. The second inequality follows because, there is a strictly positive probability $\Pr(\theta_A \leq \hat{\theta}, \theta_B \leq \hat{\theta}) = F^2(\hat{\theta})$ that the average effort will exceed the incremental payment, $w_2 - w_0 = w$.

For example, an equilibrium strategy may take the following form

$$e_2^*(\theta) = \begin{cases}(1+\alpha)(w_2 - w_0), & \text{if } \theta \leq \hat{\theta}\\ (1-\alpha)(w_2 - w_0), & \text{if } \theta > \hat{\theta}\end{cases} \quad (7)$$

for some $0 < \alpha \leq 1$. e_2^* is a fixed point of the map defined by (5) if

$$\underbrace{w_2 - C[(1+\alpha)(w_2 - w_0)\theta]}_{\text{Payoff from effort } (1+\alpha)(w_2-w_0)}$$
$$\geq (<) \underbrace{F(\hat{\theta})w_2 + [1 - F(\hat{\theta})]w_0 - C[(1-\alpha)(w_2 - w_0)\theta]}_{\text{Payoff from effort } (1-\alpha)(w_2-w_0)} \quad (8)$$

for all $\theta \leq (>)\hat{\theta}$, and

$$\underbrace{F(\hat{\theta})w_2 + [1 - F(\hat{\theta})]w_0 - C[(1-\alpha)(w_2 - w_0)\theta]}_{\text{Payoff from effort } (1-\alpha)(w_2-w_0)}$$
$$\geq \underbrace{w_0}_{\text{Payoff from zero effort}} \quad (9)$$

for all $\theta \geq \hat{\theta}$ and $\alpha < 1$. To understand conditions (8) and (9), note that any effort $e_i \notin \{0, (1-\alpha)(w_2 - w_0), (1+\alpha)(w_2 - w_0)\}$ cannot be optimal because the same probability of sale can be achieved at a lower cost. Hence, $\hat{\theta}$ must satisfy the following system of equations:

$$w_2 - w_0 = F(\hat{\theta})(w_2 - w_0) + C[(1+\alpha)(w_2 - w_0)\hat{\theta}] - C[(1-\alpha)(w_2 - w_0)\hat{\theta}], \quad (10)$$

$$F(\hat{\theta})(w_2 - w_0) - C[(1-\alpha)(w_2 - w_0)] \geq 0. \quad (11)$$

Because the right-hand side of (10) $h(\hat{\theta}) \equiv F(\hat{\theta})(w_2 - w_0) + C[(1+\alpha)(w_2 - w_0)\hat{\theta}] - C[(1-\alpha)(w_2 - w_0)\hat{\theta}]$ is increasing in $\hat{\theta}$, $h(0) = 0$, and $h(1) > w_2 - w_0$, Eq. (10) has a unique solution, while condition (11) is satisfied for any α sufficiently close to 1. Summarizing,

Proposition 2. *In equilibrium the buyer earns a positive profit under joint selling.*

4. Exogenous shocks to quality

We now show that joint selling can also be optimal in an environment with stochastic quality. Specifically, the buyer now obtains utility $q_i = e_i + \varepsilon_i$, where quality shock $\varepsilon_i \sim N(0, \sigma^2)$ is drawn independently across sellers.

Now, under individual selling, if a seller exerts effort e, the buyer accepts with probability

$$\Pr(e + \varepsilon_i \geq w_1 - w_0) = 1 - \Phi\left(\frac{w_1 - w_0 - e}{\sigma}\right). \quad (12)$$

Thus, after signing the contract, a seller solves

$$\max_e \left[1 - \Phi\left(\frac{w_1 - w_0 - e}{\sigma}\right)\right](w_1 - w_0) + w_0 - C(\theta_i e), \quad (13)$$

and e_1^* satisfies the optimality condition:

$$\frac{1}{\sigma}\varphi\left(\frac{w_1 - w_0 - e_1^*(\theta)}{\sigma}\right)(w_1 - w_0) - \theta C'(\theta e_1^*(\theta)) \leq 0. \quad (14)$$

Because, as σ goes to zero, the effort strategy defined by (14) converges to strategy (2), the buyer's profit converges to zero as well.

Under joint selling, if a seller (say seller A) puts in effort e, the buyer accepts with probability

$$\Pr\left(\frac{1}{2}[e + e_2^*(\theta_B) + \varepsilon_A + \varepsilon_B] \geq w_2 - w_0\right)$$
$$= 1 - \int_0^1 \Phi\left(\frac{w_2 - w_0 - \frac{1}{2}[e + e_2^*(\theta_B)]}{\sigma/\sqrt{2}}\right)dF(\theta_B). \quad (15)$$

Thus, after signing the contract, the seller's problem becomes

$$\max_{e\geq 0}\left[1 - \int_0^1 \Phi\left(\frac{w_2 - w_0 - \frac{1}{2}[e + e_2^*(\theta_B)]}{\sigma/\sqrt{2}}\right)dF(\theta_B)\right] \times (w_2 - w_0) + w_0 - C(\theta_A e). \quad (16)$$

The equilibrium strategy $e_2^*(\theta)$ is now defined by the following first-order optimality condition

$$\frac{1}{\sigma\sqrt{2}}\int_0^1 \varphi\left(\frac{w_2 - w_0 - \frac{1}{2}[e_2^*(\theta) + e_2^*(\theta_B)]}{\sigma/\sqrt{2}}\right)dF(\theta_B) \times (w_2 - w_0) - \theta C'(\theta e_2^*(\theta)) \leq 0 \quad \text{for all } \theta \in [0, 1]. \quad (17)$$

From (17) it follows that, as σ goes to zero, $e_2^*(\theta) > w$ for θ sufficiently close to 0 in any equilibrium under a contract $(w_0, w_2) = (0, w)$, $w > 0$. Because the buyer can refuse to buy the team's output at zero cost, this demonstrates that the buyer's profit is *strictly* bounded away from zero for any $\sigma \geq 0$.

5. Conclusions

We considered a moral hazard setting with contracts that are contingent on quantity but are not contingent on quality of the traded good, which makes incentivizing incremental efforts very costly to the principal. Our main result is that joint selling can be beneficial even though it has a heterogeneous effect on efforts, whereas efforts increase when the cost is low and decrease when the cost is high. Although in our model there is no communication within the team, the sellers have a strong incentive to collude against the buyer in order to save costs. In a static environment without intra-team transfers, the equilibrium outcome will not change in the presence of cheap talk communication as each seller will prefer to mimic the high-cost type. However, in a dynamic model with repeated interaction, the benefits of joint selling for the buyer will decrease if the sellers are able to coordinate their efforts such that low-cost sellers take turns in exerting efforts or all types choose the level of effort that leaves the buyer with no surplus in every period.[6]

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[6] This is reminiscent of the collusive pricing schemes among firms with i.i.d. cost shocks who compete for market share in the repeated games model in Athey et al. (2004).

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